TITLE: SOLID STATE JOINING OF HIGH TEMPERATURE ALLOY TUBES FOR USC & HEAT EXCHANGER SYSTEMS

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1. ABSTRACT

Program Introduction: Rationale and Objective

Our migration to advanced Nickel-base and Oxide Dispersion Strengthened (ODS) alloys, for high temperature service, poses significant challenges as these materials are not readily welded via conventional means or the welds perform poorly. For example, Ni-base alloys have proven difficult to weld *via* conventional arc-welding techniques, prevalent in the boiler industry, and ODS alloys require solid-state joining process to preserve the oxide dispersion microstructure. Thus, improving joining methodologies represent a critical developmental and design challenge that must be overcome in order to exploit and deploy advanced Ni-base and ODS alloys. The primary objective here is to develop solid-state materials joining technologies for use in forward looking heat-exchanger fabrication in Brayton cycle HIPPS, IGCC FutureGen concepts capable of operating at 1000^{o}C as well as in conventional technology upgrades *via* Ultra Super-Critical (USC) Rankine-cycle boilers capable of operating at 760^{o}C/38.5MPa steam. Our program focus is on solid state inertia welding joining of similar and dissimilar alloy tubes for heat exchanger components currently under consideration. The emphasis is to manipulate the joining methods and variables available to optimize joint hoop creep performance compared to the base material creep performance. A status report on similar and dissimilar joining efforts and their overall mechanical and creep performance at high temperature will be reported.

Accomplishments Achieved During the Current Period of Performance

During the current period of performance, January 2001 – March 2008 a series of inertia friction weld trails have been conducted for similar ODS (MA956) – ODS (MA956) butt joints and dissimilar ODS (MA956) - CCA617 butt joints. Table 1 lists the complete test matrix of MA956-MA956 butt joints produced via inertia welding where three separate test parameters, i.e., flywheel mass, weld speed and weld force are varied. We note that all test conditions provided a robust joint as evidenced by visual examination. Test#5 created an out-of joint presumably because the machine fixturing became unstable at the high weld loads employed. Test#6 produced a large material upset exceeding 0.5". This large upset is undesirable for deep-hole butt-joints as they create excessive amount of internal flash which act as constrictions for fluid flow under service conditions. With this in mind further work of microstructural evaluation and testing efforts will continue on Test Samples #1-4 (Table 1) and will be reported. Coarse grain structures are developed via recrystallization and preliminary creep testing is in progress.

Table 1: Test matrix of MA956-MA956 tube butt joints produced via inertia welding

Test	Flywheel WK^2	Weld Speed	Upset Speed	Weld Force	Weld Upset	Joint Status
1	111.5	1500	500	50,000 lbs	0.153"	OK
2	71.5	3000	500	50,000 lbs	0.498"	OK
3	146.5	1000	500	100,000 lbs	0.125"	OK
4	146.5	1500	500	100,000 lbs	0.360"	OK
5	146.5	1700	500	150,000 lbs	0.490"	Off-Round
6	71.5	3000	500	100,000 lbs	0.662"	Large upset

Plans for the Remaining Period of Performance

Work plan for the remainder of this program is as follows:

1. High temperature mechanical & creep performance evaluations of similar and dissimilar metal/alloy joints.
2. Perform similar and dissimilar metal/alloy welds for ODS-CCA617 and ODS-IN740 alloy rods/tubes in the as-received and fully heat-treated configuration
3. Microstructural evaluation of dissimilar joints from the perspective of post weld heat treatment required to develop the coarse grain structure for creep performance.
4. Report on the feasibility of inertia welding techniques for Fossil Energy applications.

2. LIST OF PUBLISHED ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS SUPPORTED UNDER THIS GRANT

Conference Presentations:
Solid State Joining of ODS Alloy Tubes, B. Kad, I.G. Wright, R.R. Judkins, 21st Annual Fossil Energy Conference, April 30th – May 2nd 2007, Knoxville, TN, Electronic CD Publication.

Student Support:
Peter Huson, Graduate Student in Mechanical Engineering, at University of California – San Diego. Another graduate student (TBA) expected to participate starting in Fall 2008.